

COSTS OF SOLIDS-LIQUIDS SEPARATION METHODS IN COAL LIQUEFACTION

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One of the major process steps in the conversion of coal to oil is the separation of the residual char or ash from the product liquid. Internal studies by Dravo have shown the cost of such separations to vary from 5 to 20% of the total product oil cost. Estimates of cost of coal derived oil range from \$15 to \$25 per bbl⁽⁷⁾ and upward providing a high incentive to recover a maximum of the oil associated with solids. Furthermore, the solids content of the product oil must not exceed .1% by weight if the oil is to be used as fuel so that the users can burn it without installing precipitators on their flue gas stacks. Also, if the oils are to be hydrotreated, solids levels less than 0.1 percent are required since fines from catalyst attrition would combine with residual solids and cause the final product to exceed this residual solids specification⁽¹⁾. Because of this separation specification, the severe operating conditions, and the propensity for plugging, coking, etc., the number of reliable process schemes is rather limited.

Dravo selected a typical liquefaction process, generally similar to Synthoil, and examined a number of solids removal systems in an attempt to find a reliable, cost effective scheme.

In the selected liquefaction process, part of the liquid product is recycled and used to slurry the coal feed to the liquefaction reactor. This feed slurry can utilize a recycle stream which has been treated to reduce its solids content from 12 to 6 weight percent. This is accomplished in a bank of hydroclones. The hydroclone feed, at 400 psig and 560°F, is split into two streams - the overheads, which is recycled to the feed preparation system, and the bottoms, which exits at 15 weight percent solids and 240 psig. This stream must now be treated further.

Several methods of secondary separation were investigated. Tests on hydroclones and centrifuges have not demonstrated the required solids removal efficiencies. Precoat filtration, on the other hand, has been successfully tested⁽²⁾. The high rates obtained when filtering the oils produced in this selected process, when compared to SRC and COED filtration rate data, increases the attractiveness of filtration. This high rate is due in part to the comparatively large amount of hydrogen consumed in the liquefaction reactor, resulting in a lower viscosity of the product oil. A preliminary screening indicated that filtration at these higher rates is comparable to other separation methods on a capital cost basis⁽¹⁾. For these reasons, it was decided to include pressure precoat filtration in the economic tradeoff analysis.

Secondary separation can also be carried out by feeding the hydroclone bottoms to the base of the product fractionator. Proper baffling should produce a sufficiently tortuous path to allow most of the solids to remain in the bottoms. This is not unlike the oil absorption tests run on COED oils, in which the majority of the solids carryover was removed in the first contact stage (bottoms), while the remaining, lighter fractions were recovered relatively solids-free⁽³⁾.

As mentioned earlier, economics dictate that essentially all the oil be recovered from the sludge produced in the secondary separation step. The oil contained in the sludge amounts to about 20% of the production rate. Some oil diffuses into the extraction solid (char) pores and remains there through capillary action. Solvent extraction or heat treatment is required to recover this oil⁽⁴⁾. Solvent extraction is currently in the development stage and requires an extra separation step⁽⁵⁾. Low pressure fluid bed dryers similar to those used in Project Gasoline were chosen as a viable method of effecting complete separation. Oil loss by coking is estimated at

4 percent of the oil fed to the dryer. The recovered char is pneumatically conveyed to a gasifier and used as hydrogen production feedstock.

Three alternate separation systems were decided on as a result of this initial screening. Case 1 (Figure 1) employs a hydroclone-rotary pressure precoat filter-fluid bed dryer solids separation sequence. The filter feed is at 200 psig and 500°F. In Case 2 (Figure 2), the filtering step is eliminated, increasing the capacity of the fluid bed dryer equipment. In Case 3 (Figure 3), the hydroclone underflow is fed directly to the base of the fractionator, which is baffled for the removal of the solids with the bottoms. The final liquid-solids separation, as previously stated, is carried out in the fluid bed dryer section. To keep the cost comparison on a consistent base, fractionation charges were included for all three cases.

Solids separation costs for this 50,000 Bbl/day facility were calculated by the Discounted Cash Flow method, using the following basis: 20-year project life, 16-year sum-of-the-years-digits depreciation on total Plant Investment, 100 percent equity capital, 12 percent DCF return rate, and 48 percent federal income tax rate⁽⁶⁾.

In addition, the following unit costs were employed in determining the annual operating costs:

Low Pressure Steam	\$2.30/MM Btu
Medium Pressure Steam	\$2.50/MM Btu
Process Water	\$.40/M Gal
Cooling Water	\$.03/M Gal
Electric Power	\$.025/KW/HR
Fuel Gas	\$3.50/MM Btu
Operating Labor	\$15,000/man/year
Maintenance Charges	3% of total installed cost for oil absorption and fractionation areas 6% of total installed cost for hydro- clone, fluid bed dryer, and drum filter areas

The following results were obtained:

	<u>CASE 1</u>	<u>CASE 2</u>	<u>CASE 3</u>
Installed Cost, \$M			
Hydroclone Area	16021	16021	16021
Drum Filter Area	25039	---	---
Fluid Bed Dryer Area	13002	39332	15665
Oil Absorption Area	2321	5635	2702
Fractionation Area	12908	12908	13153
Total Installed Cost, \$M	69291	73896	47541
Annual Operating Cost \$M/yr	25100	43566	21718
Total Separation Charges, \$/BBL	2.66	3.83	2.14

The results show Case 3 to be the least costly separations method. This seems reasonable since two operations, secondary solids separation and fractionation, are combined. Case 1 is somewhat more expensive, and would be more competitive if a higher filtration rate could be obtained. Case 2, however, is much more costly than either of the other alternates. This is mainly due to the higher capital costs required in the Fluid Bed Dryer area and the accompanying large increase in fuel gas usage.

In summary, the most economical of the liquid-solids separations methods analyzed appears to be Case 3, the combined secondary separation-fractionation alternate. Pilot tests would be recommended prior to including this system as part of a commercial facility.

OPERATING COST SUMMARY CASE I

	<u>\$M/YR</u>
<u>CATALYSTS AND CHEMICALS</u> - Filter Aid	676
<u>UTILITIES</u> - Steam	2,154
Process Water	211
Cooling Water	317
Electric Power	1,493
Fuel Gas	11,304
<u>LABOR</u> Operating	600
Maintenance	2,220
Supervision	564
<u>ADMINISTRATION AND GENERAL OVERHEAD</u>	2,030
<u>SUPPLIES</u> - Operating	180
Maintenance	1,480
<u>LOCAL TAXES AND INSURANCE</u>	1,871
<u>TOTAL GROSS OPERATING COSTS</u>	25,100
<u>TOTAL NET OPERATING COSTS</u>	25,100

OPERATING COST SUMMARY CASE II

	<u>\$M/YR</u>
<u>UTILITIES</u> - Steam	1,649
Process Water	359
Cooling Water	540
Electric Power	2,818
Fuel Gas	29,389
<u>LABOR</u> Operating	360
Maintenance	2,326
Supervisory	537
<u>ADMINISTRATION AND GENERAL OVERHEAD</u>	1,934
<u>SUPPLIES</u> - Operating	108
Maintenance	1,551
<u>LOCAL TAXES AND INSURANCE</u>	1,995
<u>TOTAL GROSS OPERATING COSTS</u>	43,566
<u>TOTAL NET OPERATING COSTS</u>	43,566

OPERATING COST SUMMARY CASE III

	<u>\$M/YR</u>
<u>UTILITIES</u> - Steam	1,649
Process Water	199
Cooling Water	299
Electric Power	955
Fuel Gas	12,844
<u>LABOR</u> Operating	360
Maintenance	1,426
Supervision	357
<u>ADMINISTRATION AND GENERAL OVERHEAD</u>	1,286
<u>SUPPLIES</u> Operating	108
Maintenance	951
<u>LOCAL TAXES AND INSURANCE</u>	1,284
<u>TOTAL GROSS OPERATING COSTS</u>	21,718
<u>TOTAL NET OPERATING COSTS</u>	21,718

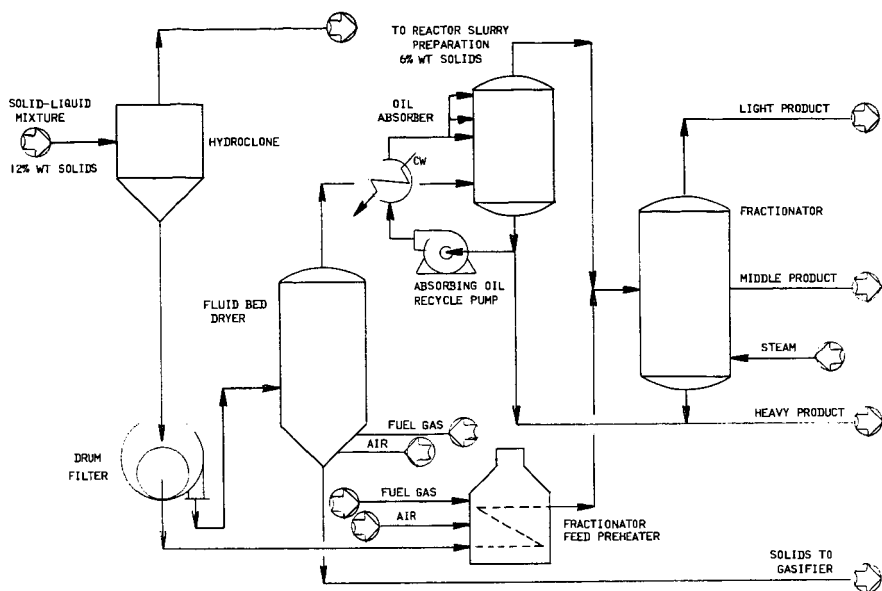


FIG.1 PRESSURE FILTRATION CASE I

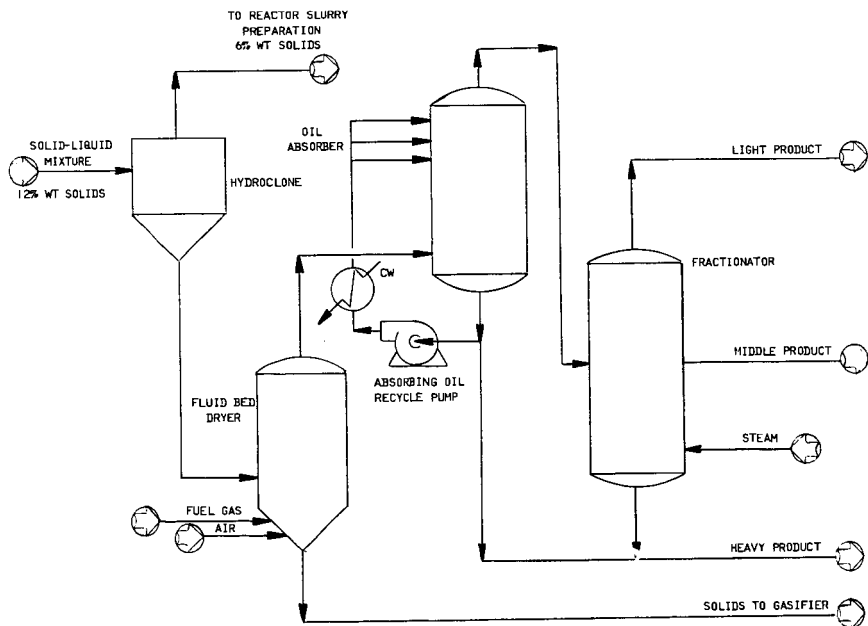


FIG.2 FLUID BED DRYER CASE II

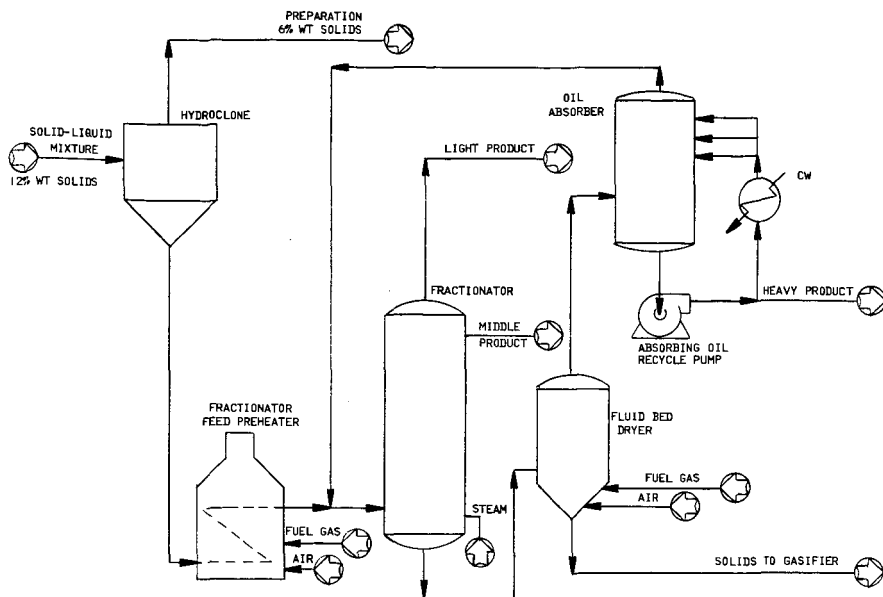


FIG.3 FRACTIONATION CASE III

REFERENCES

1. Lewton, L. C., "Evaluation of Filtration Equipment for Cresap Testing," July, 1975, ERDA, NTIS FE-1517-16, pp. 2-1, 3-1, 3-24.
2. Katz, Sidney, and Rodgers, B. R., "A Laboratory Evaluation of Precoat Filtration Parameters for the Solvent Refined Coal Process," Ind. Eng. Chem., Process Des. Dev., Vol., 15, No. 3, 1976, pp. 407-410.
3. Scotti, L. J. Jones, J. F., et al., "Multi-Stage Fluidized-Bed Pyrolysis of Coal at the Project COED Pilot Plant," 77th National Meeting, AIChE, Pittsburgh, Pennsylvania, June 2-5, 1974.
4. Eddinger, R. T., Jones, J. F., et al., "Char Oil Energy Development," December 1975, OCR, PCR-469, p. 144.
5. Rodgers, B. R., "Use Solvent to Separate Micron-Sized Particles from Liquid Streams," Hydrocarbon Processing, May, 1976, pp. 191-194.
6. Skamser, Robert, "Coal Gasification Commercial Concepts Gas Cost Guidelines," ERDA, AGA, January, 1976, NTIS FE-1235-1.
7. "Preliminary Economic Analysis of SRC Liquid Fuels Process Producing 50,000 Barrels Per Day of Liquid Fuels From Two Coal Seams: Wyodak and Illinois No.6", Bureau of Mines, Morgantown, West Virginia, 1976.